Cementless tibial baseplates can achieve stable fixation even for low bone mineral density

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Disclosures: FQG (7B: Enovis), MT (N), JL (7B: Exactech, Enovis, OrthoDevelopment; 3C: Extremity Medical), PS (3B: Depuy, Intellijoint, EOS, Enovis, Zimmer Biomet; 4: Intellijoint, Parvizi Surgical Innovation; 5: Intellijoint), KZ (N), CB (N), TY (N), HK (N), CK (3B: OrthAlign, S&N), TW (7B: Exactech, Enovis, Mathys; 5: Enovis, Zimmer Biomet; 8: AJRR, OREF, Knee Society), DM (4: Cymedica, Imagen, MiCare Path, Wishbone; 7A: OrthAlign, S&N, Stryker; 8: Hip Society, Knee Society), JV (3B: Stryker, DePuy, J&J; 4: Intellijoint, Aware, Motion Insights, Ortho AI, Polaris, Corin; 8: JBJS, AAHKS), ED (3B: DePuy, J&J; 4: Think Surgical).

INTRODUCTION: Cementless fixation of the tibial baseplate in total knee arthroplasty (TKA), which is increasingly popular, requires excellent initial stability to allow for long-lasting bone ingrowth. As such, motion of the baseplate in excess of 1.1 mm at six months is associated with increased risk of aseptic loosening,[2] which is the second most common cause for TKA revision.[3] While bone mineral density (BMD), the most important marker of bone strength, could be useful for identifying suitable candidates for cementless TKA fixation to avoid early motion,[1] the clinically relevant thresholds of BMD for stable, long-term TKA fixation have not been defined. Thus, our goal was to relate the motion of TKA tibial baseplates in the first six months postoperatively relative to their time-zero position before any weight bearing activities to the BMD underneath the implant. We hypothesized that lower preoperative BMD will result in higher implant motion.

METHODS: This prospective IRB-approved study included 17 primary TKA patients (9 female and 8 males, ages 54-76) who received robotically-assisted uncemented TKA with modern cruciate-retaining implants: three Attune (Depuy) and 14 Triathlon (Stryker). All patients received a standard-of-care preoperative CT-scan (120 kVp, 200 mA, 0.625mm spacing, 250 mm field-of-view), which included a BMD reference phantom. A reference postoperative CT-scan was obtained after patients recovered from anesthesia, before any weight bearing or manipulation of the knee. Two additional CT-scans were obtained six weeks and six months postoperatively, with a similar protocol to the preoperative scans (140 kVp, 100 mA, 0.625mm spacing, 250 mm field-of-view). The scans were resliced to 0.3mm isotropic voxels before semi-automatically segmenting the implants and bones to obtain their 3D surface representation (Mimics, Materialise). We aligned the bone from the preoperative scan to the day-of-surgery scan to determine the BMD in the 2 mm of bone immediately under the baseplate. The bone and baseplate from the six-week and six-month scans were independently aligned to the bone and baseplate from the reference day-of-surgery scan (Design-X, 3D Systems). The relative motion of the implant (i.e., migration) was calculated from the alignment matrices of the implant and bone [4] and reported as the largest motion occurring at any point in the implant (Maximum Total Point Motion, MTPM) and the directional motion of the anterior-medial, anterior-lateral, posterior-medial, and posterior-lateral corners of the baseplate. Our precision (i.e., standard deviation of zero motion in a phantom experiment) was 0.05 mm for displacements, 0.3º for rotations, and 0.1 mm for MTPM. We performed Pearson's correlation analysis between the BMD and the MTPM and the directional translations, considering a significance of 0.05.

RESULTS: The largest motion of the implant relative to the day-of-surgery occurred in the first six weeks, with MTPM ranging from 0.06 mm to 0.92 mm at six weeks and from 0.18 mm to 1.1 mm at six months (Fig. 1). On average, motion consisted of posterior-medial subsidence of the baseplate, consistent with posterior tilt of the implant (Fig. 2). The average BMD under the implant ranged from 59 mg/cm^3 to 201 mg/cm^3. Regionally, the BMD under the posterior-medial quadrant of the baseplate (176±62 mg/cm^3) was similar to under the posterior-lateral quadrant of the baseplate (154±60 mg/cm^3) and higher than under the anterior-lateral (122±36 mg/cm^3) and anterior-medial (149±57 mg/cm^3) quadrants. We did not find a correlation between the BMD under any quadrant of the baseplate and the implant motion at the corresponding corner of the baseplate (Fig. 3).

DISCUSSION: While in some cases motion was close to the limit of acceptability at six months for uncemented (1.1 mm) TKAs,[2] our study is the first to report implant migration relative to the time-zero implant position, prior to any manipulation as reference. We observed that implant motion was compatible with stable fixation, even for patients with regional BMD as low as 45 mg/cm^3. In this way, all baseplates in this study have remained well-fixed. While we did not find an association between BMD and implant motion, our study did not consider the effects of joint loads.

SIGNIFICANCE/CLINICAL RELEVANCE: a threshold of density for cementless fixation has not been defined and our study suggests that cementless fixation can be successful even in patients with low regional bone density under the implant.

ACKNOWLEDGEMENTS: This study received funding from the generosity of the Kenneth C. Griffin Research Accelerator and the Stavros Niarchos Complex Joint Reconstruction Center at HSS.

References: [1] Borsinger et al., J Arthroplasty, 2024; [2] Puijk et al., Acta Orthop, 2025; [3] AJRR Annual Report, 2023; [4] de Laat et al., J Orthop Res, 2025

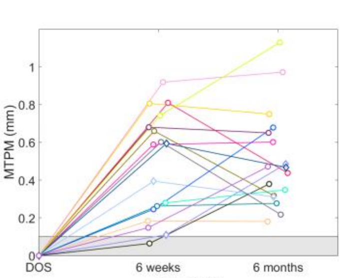

Fig. 1 – evolution of the MTPM

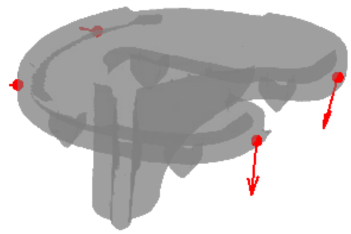

Fig. 2 – On average, motion consisted of posterior subsidence

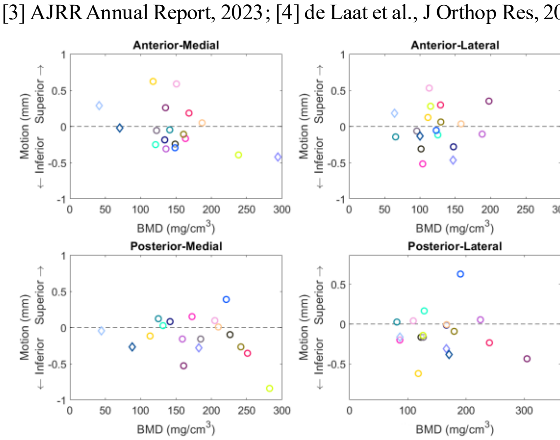

Fig. 3 –Implant motion was not correlated with the bone mineral density at any location underneath the baseplate